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VIRTUAL PROTOTYPING SYSTEM

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14. ABSTRACT
Chemical, Biological, Radiological, and Nuclear (CBRN) defense equipment cannot be tested or evaluated in conditions closely approaching an operational employment. Although not replacing actual testing, computer simulation can overcome most CBRN safety and environmental testing concerns, allowing system evaluation in an operational contest. Functioning as either a stand-alone or distributed process, the Virtual Prototyping System (VPS) addresses the importance of assessing CBRN defense systems and concepts in realistic conditions and satisfies the need for compliance with Simulation Based Acquisition guidance. The VPS is a Modeling and Simulation (M&S) tool designed to define and evaluate CBRN defense equipment throughout all phases of the acquisition life-cycle. The goal of VPS is to represent the CBRN defense system functionality with appropriate fidelity for the particular analysis or assessment. The system evaluation includes the interactive and interdependent relations between the systems, components, and subsystems. VPS supports functional assessments to include requirements generation, system engineering, and operational worth evaluation. **The leveraging of existing DoD M&S capabilities for CBRN defense system analysis is fundamental to the VPS concept**. By using existing community M&S resources (e.g., libraries, models, and simulations), significant economy of cost and time is realized in VPS development and implementation.

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PREFACE

The work described in this report was authorized under Contract No. DAAD13-02-C-0008, (BAA), Virtual Prototyping System. The work was started in January 2002 and completed in December 2003.

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VIRTUAL PROTOTYPING SYSTEM

1. INTRODUCTION

1.1 Report Description.

This report contains an overview of the Virtual Prototyping System (VPS) modeling and simulation capability that has been developed for the CBRN Defense community over the years. The VPS role, need, concept, and context within Simulation Base Acquisition SBA are presented in Section 1. Following sections provide details of: the VPS design and description (2.); GUI and architecture details (3.); a proof of principal and use example (4.); and a review of current status (5.).

1.2 Report Objectives.

The major objective of this report is to demonstrate the critical role of VPS in CBRN defense systems acquisition. This objective is met by:

- The presentation of the VPS as the major, viable and necessary capability in CBRN defense systems acquisition,
- The VPS application definition,
- The presentation of the tool specifications
- Providing an example of VPS use

A second objective is to document the current status of VPS. This documentation includes the work performed during the FY03 effort.

1.3 Functional Role of VPS.

Presently the CBRN M&S community acquisition lacks a standing capabilityto interactively link materiel development and combat development/planning into a common continuum of experimentation, evaluation and analysis. Because live testing of CBRN defense systems is necessarily quite restricted, the capability to link system development with combat development in an operational context is particularly difficult, if not impossible. However, knowledge bases created by analysis of tests performed in operational context are critical to understanding operational worth and performance use of CBRN defense systems.

At present limited testing of CB system components can be accomplished with live agent under very controlled laboratory conditions. Field tests of CB systems can only be performed with simulants and not under conditions closely approaching operational employment. Yet understanding the CB environment impact on the functionality of a given CB system and on the functional relationships between it and various combat systems is critical to the designer, combat planner, analyst, and warfighter in assessing and evaluating such systems.

The most plausible alternative to live testing is simulation testing. This approach requires the virtual representation of systems, concepts, and tactics, techniques, and procedures (TTP) in a synthetic environment. Recognizing the significance of virtual tools for development, testing and analysis, the revised DoD 5000 series includes the development of M&S virtual prototyping capabilities as important to the acquisition process (Appendix A). The VPS provides the solution to CBRN modeling and simulation in support of SBA and offers an important element of force preparation.

The VPS M&S application provides the means for integrated, virtual CBRN testing and analysis and facilitates the linkage between CBRN engineering and combat developers throughout the acquisition cycle. This is accomplished with a robust modeling and simulation platform on which systems, systems-of-systems, and family-of-systems are evaluated and assessed in realistic, virtual operational environments. Implicit to the success of this approach is the VPS ability to perform meaningful analyses on the results of a simulation.

VPS ability to model CBRN defense systems gives it relevance in the three DoD established functional areas of M&S activity: ACR, RDA, and TEMO. Because VPS can operate in a distributed environment, a fully functioning VPS provides interconnectivity between CBRN defense systems development (e.g., Edgewood, Dahlgren, SPAWARS), testing (e.g., Dugway Proving Ground, Eglin AFB), and combat development (e.g., Fort Leonard Wood, Quantico, Tyndall AFB) centers throughout the DoD. Although it is not a warfighter's tool, VPS functionality and capacity for interconnectivity provides beneficial use to the warfighter.

As an M&S tool for SBA, VPS offers the following benefits:

- Realistic, high-fidelity virtual test environments for engineering assessments
- Realistic, virtual combat environments for assessing operational worth and performance use
- Variable fidelity of model representations for CBRN defense systems
- Linkage between system developers and combat developers throughout the acquisition life cycle
- Facilitates early warfighter interaction in the acquisition cycle
- Leverage existing community CBRN M&S resources (modularity, reusability)
- Ease of varying tactical and physical contexts for the evaluations

1.4 VPS Concept.

VPS is an M&S tool that can be used by a variety of users, ranging from design engineers to combat analysts to systems trainers. Conceptually, the Virtual Prototyping System tool is a process that enables the assessment and evaluation of CBRN defense systems throughout all phases of the Acquisition Process, from concept exploration through operations

and sustainment. VPS users with subject matter expertise will be able to perform their tasks from a single station and will not need to be M&S experts.

VPS enables implementation of Simulation Based Acquisition (SBA) in the CBRN community. In this context VPS has particular relevance in systems concept and design studies, allowing for the refinement of design prior to prototype builds, testing in virtual CBRN environments and operational conditions, and early interaction with combat developers and warfighters. Additionally, VPS contributes to total force preparation, providing modeled CBRN defense systems for operational simulations and simulators performing operational worth and performance use evaluations for commanders.

To be in line with DoD policy, computer codes and applications should be interactive and modular. Too often, however, the propensity has been to develop stand-alone, special purpose codes. Contrarily, a key design feature of VPS is modularity, which establishes a very robust and versatile M&S tool. Importantly, the VPS is not intended to be a monolithic end-to-end simulation but rather the mechanism by which detailed representations of conceptual/developmental CBRN defense systems can interact with other simulations/simulators within a synthetic environment.

A feature that distinguishes VPS from other M&S development capabilities is its ability to perform integrated CBRN defense system level evaluations as opposed to individual system component evaluations. Currently the M&S community models CBRN defense system components (sensors, optics, electronics, etc) independently, but the modeling of the integrated components in the context of the system is not available. The CBRN community also lacks a system-of-systems and a family-of-systems capability that is provided by VPS. VPS addresses these deficiencies and enables assessment of the total CBRN defense system in terms of experimentation, operational worth, and performance use in context of the combat environment.

The principal function of M&S is analysis. VPS links model and simulation data and results with VPS and external analysis tools. These tools are applied at various phases of CBRN defense system development and different in scope. For example, analysis tools for system concept and design typically will need to include operational context. On the other hand, analysis of CBRN defense system operation worth will require an operational context but will not need to include system component level context.

Inherent to VPS is the capacity for conceptual analyses. Engineers will have the capability to design and modify CBRN defense systems at the component level and then analyze the integrated system performance in operational context. Other applications include engagement simulations that would use planned and notional systems and capabilities projected for future combat environments. Results will help evaluate operational worth and performance use of projected CBRN defense systems and provide a situational context for the future battlefield environment.

VPS simulations are not meant to replace live testing. However, the use of VPS can certainly establish ranges of operation and identify unreliable designs. Simulations can also help focus limited testing resources and capabilities. Results of simulation testing may be used to extrapolate test data to other operational contexts.

1.5 Need for VPS.

Needs for the VPS capabilities within the CBRN defense community are threefold: (1) the need for efficient and cost effective development of operationally useful CBRN defense equipment, (2) the need to assess CBRN operational worth and performance use, and (3) the need to meet defense acquisition mandates and guidelines.

VPS finds multiple applications among analysts, requirements generators and combat developers, wargame(s), schools and trainers, material engineering developers and testers. The need for multiple applications is supported by lessons learned and feedback from a broad spectrum of users. (See Section 5.2.2 and Appendix B.) VPS provides not only a mechanism for system development and engineering, but also for system-of-systems development and conceptual use of systems in operational, testing and training contexts. Implementation of VPS allows early system definition resulting in cost and time reduction in the acquisition cycle.

The VPS design is robust. While it is being developed with some specific applications in mind, the total sum of user desires and applications is not supposed. It is expected that once available to the CBRN community, users will find unique or unrealized applications for VPS. With this in mind, elements such as Open Architecture, distributive capability, and adherence to IEEE, DIS and HLA standards are built into the VPS.

1.6 Support of SBA and Acquisition Benefits.

The VPS is an enabling capability for implementing SBA in CBRN acquisition process. The Virtual Prototyping System is specifically designed to define and evaluate CBRN defense systems in support of the SBA, DoD 5000 series revision intent and acquisition policy, and CJCSI 3170. Appendix A briefly highlights pertinent items concerning M&S in acquisition reform and VPS relevance in context of Acquisition Policy.

It is noteworthy that the VPS and SBA concept has been heartily embraced by many developmental communities in both commercial and military applications. The Boeing Corporation and automotive companies, among many others, as well as military acquisition categories ACAT 1 and 2 developers have used VPS-type tools for years.

However, the CBRN development community has not yet embraced VPS concepts to a large extent, possibly because tools being used are not widely known and because their use involves a paradigm shift from historical ways of doing business. Another very-difficult-to-overcome reason is that articulating a strong requirement for VPS-like tools has not yet occurred. For ACAT 1 and 2 programs, developers are required to use VPS-type tools. CBRN defense equipment usually falls in ACAT 3 and 4, which have much less stringent requirements and funding devoted to extensive modeling development and analysis.

Conceptually the cost and time benefits of VPS are illustrated in Figure 1. Based on information compiled from numerous acquisition programs, qualitative cost vs. time curves for historical acquisition life-cycles and current acquisition reform life-cycles are displayed by black shadowed and red curves respectively. Current acquisition policies have significantly reduced time and cost during the acquisition cycle. One of the main reasons for this is the

emphasis on early identification of design and performance problems and issues. This emphasis has the effect of increasing the cost of the initial phases of acquisition but creating substantial savings later in the acquisition cycle.

Implementation of the VPS is expected to further increase initial development and design costs as shown by the white curve in Figure 1. However, because the developing systems can be tested in a realistic, virtual combat environment and because the combat developer is included in the design and development M&S, additional savings in cost and time are realized over the entire life-cycle.

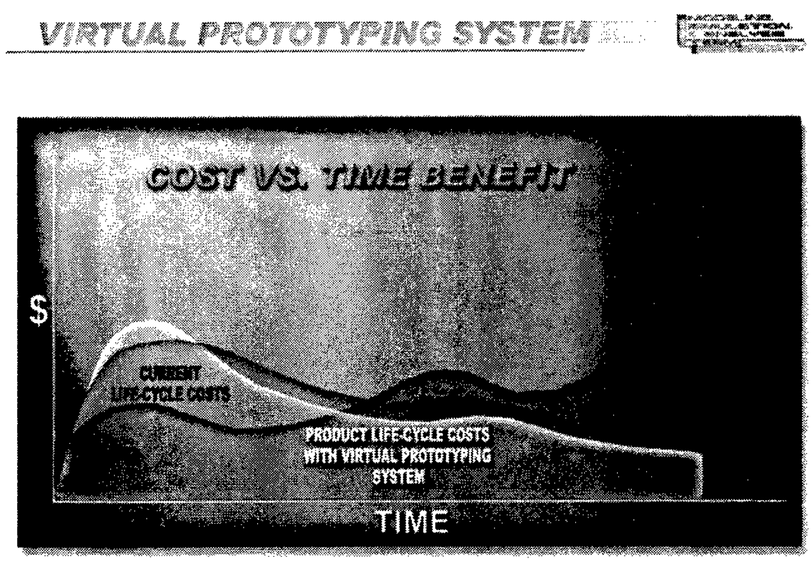

Figure 1. Notional VPS Impact on Life Cycle Costs. (Current Life-Cycle and Historical Product Life-Cycle Graphics from Defense Acquisition University Course Acquisition 101)

Reusability of many VPS modules and libraries (terrain, weather, communications, etc.) is another benefit of the VPS. The initial cost of future development programs will decrease, benefiting from the efforts of earlier programs.

1.7 <u>VPS Development</u>.

Development of VPS will be based on proof-of-concepts simulation used to support developmental, analysis, training and testing efforts by the JSCBD Tech Base, JPEO CBD Acquisition Programs, DOD Test Ranges and Operational Support Organizations (such as JFCOM and MANSCEN). The envisioned simulation system will be able to operate at specific sites for focused evaluations or distributed to many sites for robust Joint Task Force (JTF) engagement assessments of engineering alternatives. Results of the technology development effort will directly transition to the VPS program under the JPM Information Systems.

Given the scope and complexity required for a fully capable VPS, the development will necessarily be phased within the two application modes described in Section 2.

1.8 MS&A Team Relevant Background and Experience.

Collectively, the MS&A Team has decades of experience supporting efforts in the CBRN defense system arena, including the use of MS&A for SBA applications. Team members have diverse backgrounds that include researchers, material and combat developers, laboratory and field testers, and warfighter veterans from all service branches. This collective experience and diversity of background give the Team a unique capability for designing, developing and implementing a viable and robust VPS.

Because of its extensive MS&A support of the CBRN community, the Team has attained an authoritative understanding of M&S issues pertaining to CBRN defense systems, meteorological models, transport and diffusion models, CBRN parameters and mechanisms, HLA/DIS architectures and operations, and CBRN community resources. The Team's knowledge extends to engineering models and decision aid M&S throughout the Joint community.

The Team has played essential roles in the development, implementation, and analyses of such M&S applications as Dial-A-Sensor, the NCBR simulation, and the BioSIM experiment (Section 4.). In addition, the Team members have developed and used for analysis the Sensor Obscuration Engagement Simulation (SOES) and the Smoke System Performance Model (SSPM) / Cloud Density Visualization Use (CDVis). The SOES and SSPM analyses were SBA applications using M&S for the Army's Obscurant Program.

Through its experience and understanding of MS&A relative to CB defense systems, the Team has recognized the need for and the value of VPS as articulated by material and combat developers in support of the acquisition process. Based on its experience, expertise and insight, the Team has developed the VPS concepts presented in this report. The Team not only has the technical knowledge to successfully develop and implement VPS but also has the acquisition knowledge to ensure a smooth transition. Additionally, the Team has the analytical experience to judiciously apply VPS.

Section 4 highlights one of many successful Team activities in the CBRN MS&A field and demonstrates the Team's skill in helping to develop and implement a VPS-like simulation. Section 5 documents the Team's experience and efforts specifically concerning VPS.

2. VPS DESIGN AND DESCRIPTION

2.1 Overview.

A high-level view of the VPS concept is presented in Figure 2. Shown is the VPS environment that includes the VPS GUI, VPS libraries, the VPS Process (e.g., engineering, modeling, simulation applications, etc) and the distributed applications. Examples of HLA (or DIS) distributed applications are additional CBRN defense system libraries and model sources, environment models (e.g., JEM, VSLTRACK), and operational context simulations (e.g., OneSAF, JOEF, JSAF, JCATS). Within the VPS Process reside the modeled CBRN defense system and the simulation. The VPS Process, through user direction, provides the means for

executing the simulation of interest. As noted, the VPS libraries include internal archives as well as external sources. Implementation of external applications (distributed process) is controlled through the VPS GUI. Data required to run external applications can be provided by the user, or by selection of existing VPS library files, or by selection of external files. Details of the various VPS elements are described in Section 3.

The "CBRN Hardware" and the "CBRN defense equipment simulators", components on the right side to the distributive architecture (HLA), are entry points for virtual simulations. It is through these components that human in the loop is supported. The VPS user will be able to trigger these components from the VPS GUI.

Shown at the top of the HLA pipe in Figure 2 are Joint Evaluation and Experiment spaces. The Joint National Training Capability (JNTC) will be offering shared evaluation and experiment space in which emergent systems need to participate. The VPS allows for the linking of CBRN defense systems into the SAF based virtual component of the experiment or evaluation space of the JNTC.

2.2 VPS Application Modes.

VPS is designed to support two distinct application modes: (1) the engineering application mode, and (2) the engagement application mode. These are not "stove pipe" modes but identify the type of VPS user and application. In either mode there is considerable overlap and integration of the VPS functions and resources.

To support the two application modes VPS provides a common set of fundamental capabilities and resources. These include a Graphical User Interface (GUI), the software toolset that models CBRN defense systems, libraries that define system components and their operating parameters, libraries that define environmental and combat environments, distributed communications interfaces, and analysis tools for evaluating system functionality in realistic, virtual environments. VPS is designed to operate on a Personal Computer or Work Station in either as a stand-alone (primarily but not limited to the engineering application mode) or distributed process using HLA/DIS (primarily but not limited to the engagement application mode).

Fundamental VPS functionality is realized through a modular approach to modeling integrated CBRN defense systems. Modularity requires individual component models that are maintained in the VPS libraries or supplied by the user. Evaluation of individual component modifications is then accomplished within the context of the integrated system performance. This approach allows engineer and combat developers to evaluate and optimize the CBRN defense system rather than just the individual components. This is an important point because, depending on power requirements, cycle time, weight, etc., optimization of one system component may possibly degrade the overall system performance or render the system concept untenable.

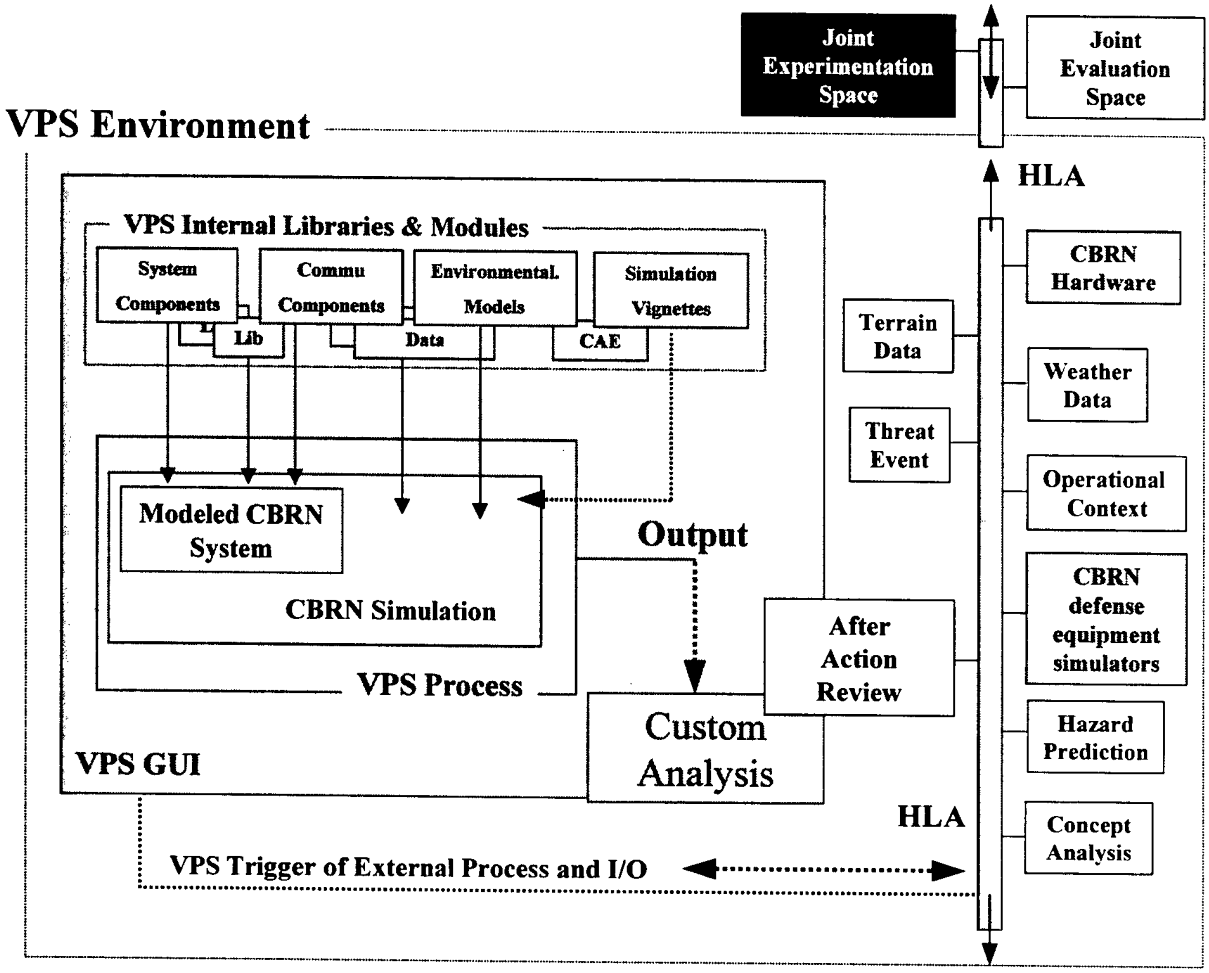

Figure 2. VPS Environment. Major functional elements of VPS include the VPS GUI, VPS internal libraries, models, and modules, VPS engineering tools, VPS analysis tools, and the distributive application.

It is important to note that VPS <u>only</u> models CBRN defense systems. The required component models and simulation environments needed for system evaluation are drawn from community sources. The VPS internal libraries, built from community information and data, are established to support stand-alone simulations; external applications, libraries, and data sources are used to provide additional repositories and supplement or replace internal libraries in the distributed operation.

The above point, leveraging of community resources (libraries, models, simulations, simulators, etc) is fundamental to the VPS design concept. That is, the use of existing M&S community resources significantly reduces the cost and time of VPS development and implementation. This approach is compliant with modularity and reusability guidance included in acquisition strategy.

2.2.1 VPS Engineering Application Mode.

In this mode the systems designer uses VPS primarily through the earlier decision points and phases in the Acquisition Management Framework established by DODI 5000.2 in May 2003. These decision points include: Concept Decision, Milestone A, Milestone B, and Design Readiness Review; the phases include: Concept Refinement, Technology Development, and System Development and Demonstration.

In the engineering mode design tools are used for high fidelity performance and trade studies. This application of VPS concentrates on combining engineering concepts and models with realistic physics and environmental conditions to determine optimal system design. This mode will normally use limited tactical reality simulations.

Design applications will normally employ a stand-alone engineering toolset and be used by material developers and Program Managers. The engineering application mode capability allows the engineer/developer to sit at his or her workstation and ask, "what detector design (or other piece of CBRN equipment) parameters are necessary to meet required performance characteristics?"

In this application, the engineer/developer uses menus or point and click to establish all the sensor (equipment) characteristics, such as flow rate, sensitivity, range, failure rates or whatever is applicable to the CBRN defense system at hand. The developer builds the CBRN defense system model from the individually modeled components through drag and drop technology. The developer also specifies the environment in which he wishes to simulate system operation and function. This standalone application would rely on databases of pre-computed attacks and challenge levels. The software would be distributed on a CD and installed by the developer-user.

The systems developer will occasionally want to test the system in a realistic operational context. In this instance the developer will probably want to take of advantage of the VPS distributive capabilities, using such applications as OneSAF, etc to create operational simulations.

With the VPS tool, the systems developer is only responsible for constructing a model of the specific system or concept being developed or considered. The operational worth and performance use can then be analyzed in the larger operational context, accounting for physics and natural phenomena provided by VPS. The results and residual simulation capability can be passed on to combat developers, testers and trainers for their use with little or no modification.

Major benefits of this VPS application mode are the ability to affect design changes and test modifications before actually building prototype hardware and, because of the inability to test systems with live or actual CBRN materials and effects, to provide the high fidelity, virtual combat environment that allows an engineering assessment of the proposed system performance. These benefits led to:

- Early identification of requirement solution concept(s)

- Early prototyping prior to build
- Early determination of value
- Earlier consideration of costs/impacts
- Inclusion of designer into the operational worth equation

The sum of the above benefits is expected to positively impact cost, time, operational worth, and performance use.

2.2.2 VPS Engagement Mode.

Combat developers and analysts will use the VPS tool in engagement mode for operational worth and performance use assessments. In this mode the Acquisition Management Framework areas of interest range primarily from Concept Development and pre-MS A through the FRP decision point review and include phases of System Development and Demonstration, Production and Deployment, and Operations and Support.

The engagement mode is focused on constructive & virtual simulations and it is expected that most applications in this mode will be distributed over an HLA Federation. Realistic tactical environments with realistic and engineering level physics will be employed and people/equipment/systems in the loop can be implemented. Requirements or specification generation, concept exploration, and component or feature performance evaluations as well as engineering trade off analyses will be enabled.

As noted in Section 1, VPS is not a monolithic end-to-end simulation but rather the method by which detailed simulations of conceptual/developmental CBRN defense equipment can interact with other simulations/simulators within a synthetic environment. This methodology is established to evaluate the range of CBRN defense system utilities in an operational setting. VPS might be considered as the high-resolution analog to what operational decision aid tools do for decision aids, force structure or equipment issues. These tools provide assistance in, for example, determining the number of standoff detectors needed in a specific situation with a certain probability of detection. VPS looks at what detector designs and characteristics are required to achieve the operational capability and what elements of the detector design can be traded off to achieve the end result, VPS may actually be the mechanism used to determine the data look-up tables for operational decision aid tools. This resolution partition of the SBA trade space is shown in Figure 3.

The key distinction between operational decision aid tools and VPS is principally the user base, resolution and output. Operational decision aid tools are geared toward providing operational decision aids for staff action. VPS is geared to high resolution engineering development, performance evaluations and operational worth and performance use assessments.

Even though VPS is primarily a CBRN M&S engineering and engagement tool, VPS can play a vital role in the operational decision aid arena. As indicated in Figure 3, VPS analysis and simulation results of high fidelity studies regarding CBRN defense system responses, actions, and interactions in operational environments can be forwarded up the M&S

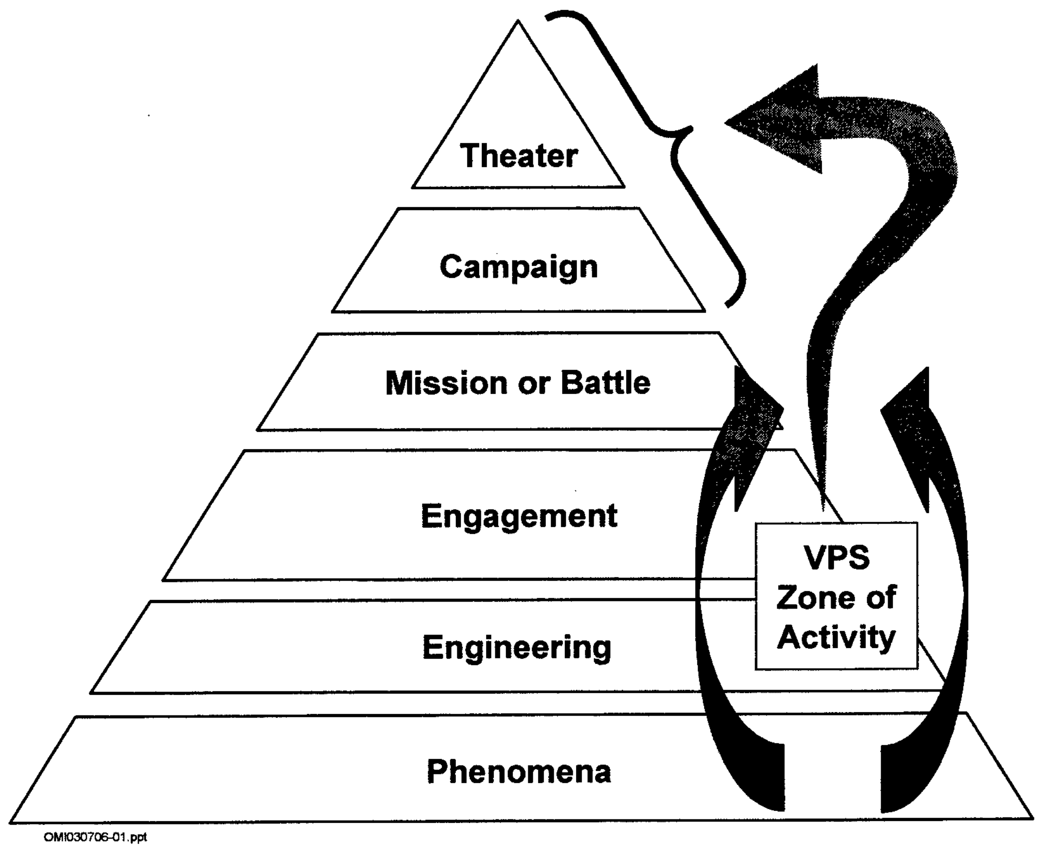

**Figure 3. VPS Application in the M&S Hierarchy.
VPS high fidelity studies can provide information and data for
operational decision aid tools.**

hierarchy as inputs into operational decision aid tools. Information relating to CBRN effects on operations tempo, causalities, etc will be improved. This use affords the operational decision aid tools better characterization of the battle environment and strengthens the validity of decision aid outcomes and analyses.

3. VPS ARCHITECTURE

Details of VPS architecture are evolving as lessons learned from the proof-of-principle experiments (e.g., Section 4) and the input from the user community is integrated into the VPS concept. At present a workable architecture now exists. This first-tier VPS architecture is presented in Appendix D.

3.1 Implementation of Architecture.

Any VPS will have the components as shown in Figure 4. This is a very basic representation and does not describe some of the complexities that may be inherent in the component pieces (Figure 4 boxes). Not indicated in Figure 4 is what constitutes the core

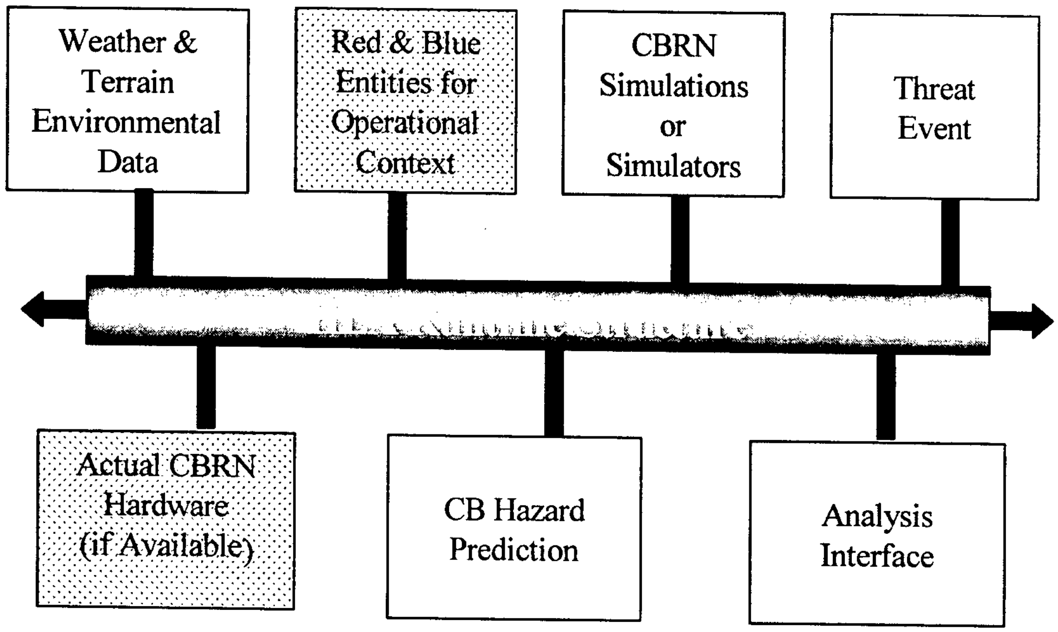

Figure 4. Common Components Required in VPS Architecture.

functionality of the VPS; that is, the interfaces and code, such as the VPS GUI, that enable the components to interact.

Aside from the GUI, major work will be required on the components denoted by the gray boxes, i.e., the CBRN Simulations or Simulators, and the Analysis Interface components. The components denoted by the speckled boxes, "Actual CBRN Hardware" and the "Red/Blue entities for operational context", will need code work but not to the level of the components in gray. The remaining components would require minimal development under VPS as long as these components adhere to the HLA interface standards. For specific CBRN hardware development or analysis, modification of the components may be required, but this investment can be recouped as an embedded training capability during the fielding and sustainment phase of the system's lifecycle.

Output of the various components will have to match assessment needs of the CBRN defense system to be evaluated. For example, if a point CB sensor is being prototyped, the hazard prediction software may only have to "publish" (make available on the network) time histories of the concentration accumulated at specific points on the battlespace. However, a further refinement requiring component modifications might require information concerning agent optical properties, particle size distributions, relevant atmospheric properties and interferents. The level of fidelity required and the variety of data required will depend on the sensor technology sensitivity to these parameters.

Similarly, if a standoff detection system were being evaluated, the hazard prediction software would have to publish three-dimensional cloud data. Additional data may be required, such as particle size distributions, instantaneous concentration, agent optical properties, and atmospheric conditions and properties (e.g., winds, temperatures, barometric pressure,

aerosols, gases, and particulate matter present). Again, the data required and the fidelity will depend on the detection technology being developed.

The two key components of development for VPS, CBRN Simulations/Simulators and Analysis Interface, will have elements that are both JSTB sponsored and individual PM or materiel developer sponsored. Under the JSTB portion of VPS, both components will be built to address generic capabilities like a point biosensor that uses particle counting as a trigger or standoff chemical sensor using passive IR technology or a semi-permeable protective garment. The capabilities to evaluate these generic classes of CBRN equipment will be in the main VPS program.

Ideally the VPS modules and interface will be highly adaptable and robust so that any combat/materiel developer would only have to alter input data sets and select analysis options from existing choices. The knowledgeable user will have the ability to build custom libraries, models, modules, etc. The PMs will have the responsibility for integrating multi-functional changes back into the general distribution version of VPS. This process is at the heart of the SBA tenet to develop reusable and interoperable M&S tools. Therefore, the development and maintenance of a common core capability for the CB Defense Community is desirable.

<u>VPS Graphical User Interface (GUI)</u>.

One of the major coding efforts in developing the VPS tool will be the construction of the Graphical Use Interface. This interface is the user gateway to engineering and engagement applications, providing for virtual testing of design, development, and operational worth and function within the context of realistic CBRN environments. The GUI provides linkage and access to such varied applications as Computer Aided Engineering (CAE) applications for engineering level system design to access of environmental and parameterization libraries to engagement applications such as OneSAF.

A notional, high-level design for the VPS GUI is graphically illustrated in Figure 5. This design is considered representative of the VPS GUI concept but not comprehensive or final.

The overall structure of the GUI has a standard "look-and-feel" familiar to most program application users. It uses menu bars, drop down menus, drag-and-drop, etc that are prevalent in modern computer software. The VPS design logic facilitates ease of use and will offer intuitive process flows. To facilitate CBRN defense system design and component linkage, the GUI engine is projected to be a MATLAB™-like COTS application.

Figure 5 shows an example simulation process involving the selection of a Detection Component Technology block (DC1) of the overall CBRN defense system, being linked to a Radio Data Network (RN1) and using a Data Transfer Technology block (DT1). Each of these modules is a default set of engineering structures obtained from engineering and system libraries of high fidelity inputs and/or models. Library pulls may be from CAE files, engineering simulations, or other known sources. They may be default components of the system, design concepts, or some other element of the CBRN defense system. Once appropriately installed into the Operation Field via drag and drop, the user can accept the default

values, adjust values within the control tables, or set external sources using a set of link types (not shown but involving arrow types, colors, etc. for specific functionality). The user then indicates number of desired iterations of the simulation run as required. The selected modules are tracked via the Selected Processes Field and are saved for future repeat analysis of the run. The indicator control 'traffic light' is a representation of a debug process that ensures the appropriate and authorized inputs and/or links are present.

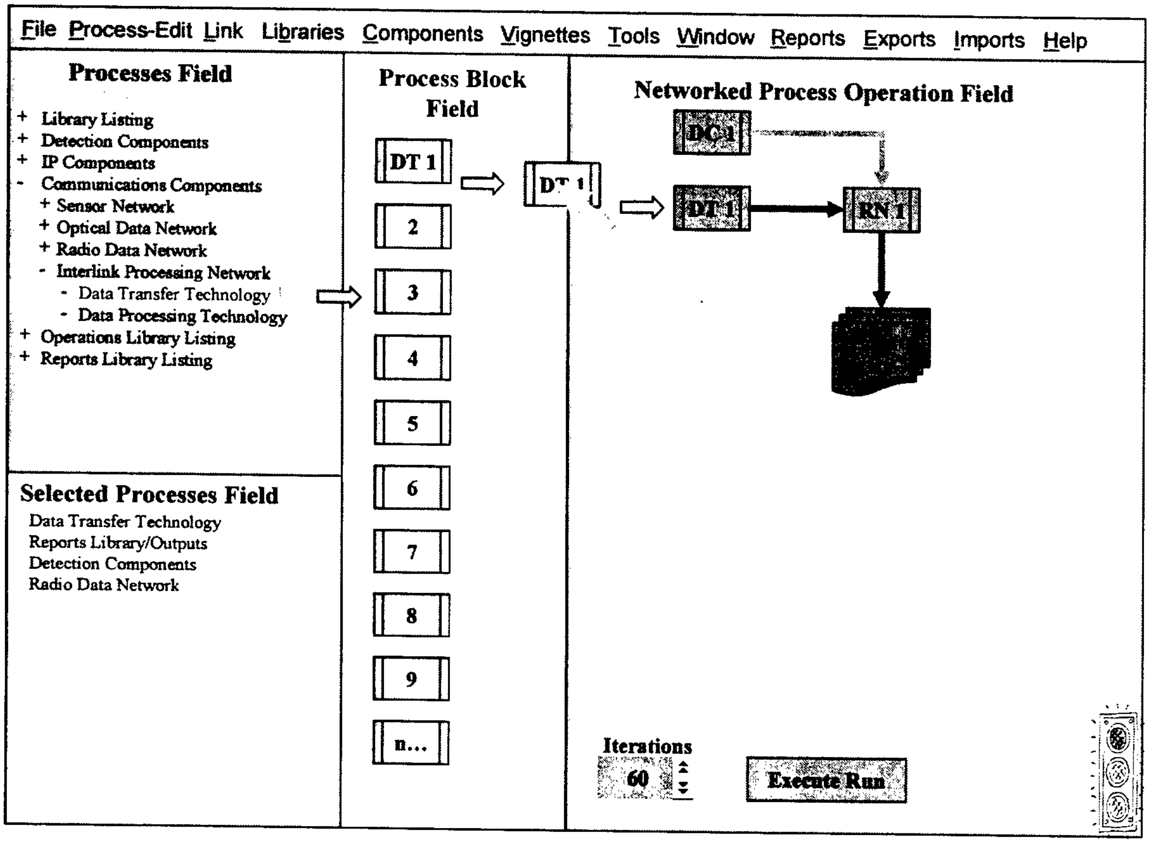

Figure 5. Notional VPS GUI Overview. Components of VPS are accessed, initialized, implemented, and linked through the GUI.

The results are stored to the appropriate Report location(s)/file(s)/output link(s). This data can then be used for stochastic, parametric, or other analysis as needed. Internal to the VPS structure, the data may be run against low fidelity, closed-value vignettes within a simplistic operational simulation. This provides 'goodness' estimates particularly useful in 'what-if' assessments. The data may also be exported via ASCII, text, or other format for use in high fidelity operational simulations external to the VPS structure. This capability enables assessment of the CBRN defense system, with desired/required modifications, at the force structure and requirements levels.

3.2 Current Capabilities.

From an acquisition development standpoint a Block IA capability of the VPS exists. The components that make up this initial capability are shown in Figure 6. A very similar architecture was used during the BioSIM experiments described in Section 4.

There are other components that represent various detection technologies like standoff LIDAR (laser detection and ranging), and various other passive and standoff detection technologies. The least mature component of VPS is a robust analytical module. Current analyses still involve a hefty amount of manual data transfer, and the M&S tools are very specific to the task at hand. When the network was based on distributed interactive simulation (DIS) protocols, commercially available data loggers were used for data capture and some limited analysis.

4. PROOF-OF-PRINCIPLE AND USE

The U.S. Army Soldier and Biological Chemical Command M&S conducted several simulation experiments using VPS-like concepts, beginning as early as 1998. (These experiments were conducted prior to initiation and funding of the VPS Technology Base program. The design, architecture, simulations, and results of these experiments significantly contributed to and influenced the VPS concepts and effort to follow.) The experiments, called BioSIM, were performed to establish tactics, techniques, and procedures (TTP) for a standoff detection system, the LR-BSDS. The successful assessment of the LR-BSDS system demonstrates the VPS engagement mode concept in a distributed environment and serves as the VPS proof-of-principle. The limitations of the BioSIM distributive simulation architecture were:

- Normally disassociated simulations were modified to enable direct linkage at some expense in time and resources.
- The simulations used did not permit stand-alone (non-distributed) capability.
- The simulations were DIS compliant.

Current versions of the simulations used in BioSIM are HLA compliant.

4.1 Analytical Process as a VPS Proof-of-Principle.

The VPS concept viability was demonstrated in 1998 using supporting both the engineering and engagement application modes discussed Section 2. The baseline scenario for this study involved the Long-Range Biological Stand-off Detection system (LR-BSDS) performed by the (then) Edgewood Chemical-Biological Center M&S Team. A distributed simulation infrastructure was used to develop tactics, techniques, and procedures (TTP) of employment. Figure 7 depicts the support structure for this analysis.

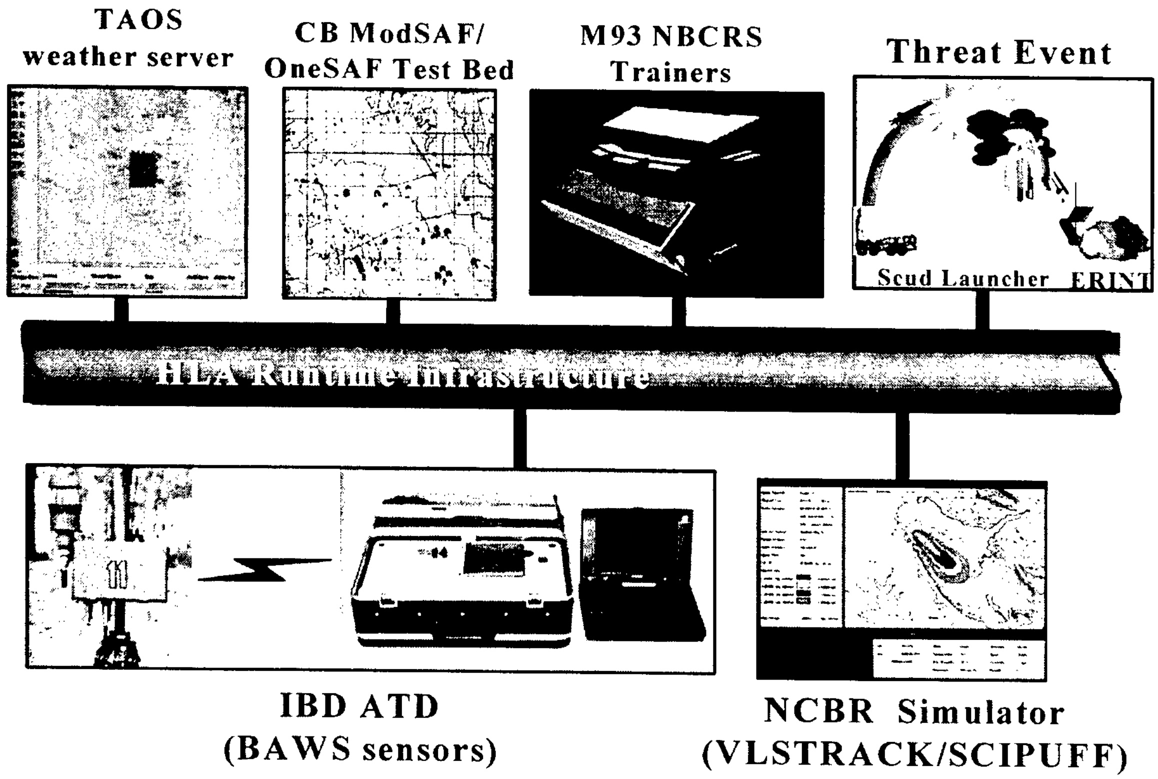

Figure 6. Current VPS Capabilities.

Two distinct BioSIM experiments were conducted illustrating the modularity designed into VPS. The first experiment used ModSAF entities to simulate the UH-60 flight characteristics. In the second experiment the UH-60 flight simulator at the Ft. Rucker Army Aviation Test Bed provided the helicopter flight characteristics. The second experiment also included aspects of the VPS engineering mode by implementing software modifications in the LR-BSDS operational parameters.

The study was performed using existing DIS-compliant simulations. As shown above, the various elements of the system were simulated using:

- The NCBR Environment Simulator for the agent dynamics,
- The flight frame simulated by ModSAF (experiment 1),
- The flight frame and man-in-the-loop dynamics by a UH-60 flight simulator (experiment 2),
- Terrain and cloud dynamics by the MaK Stealth simulation
- ADA threat by ModSAF, and

- Detector system and operation (man in the loop) by a LR-BSDS trainer with DIS interface.

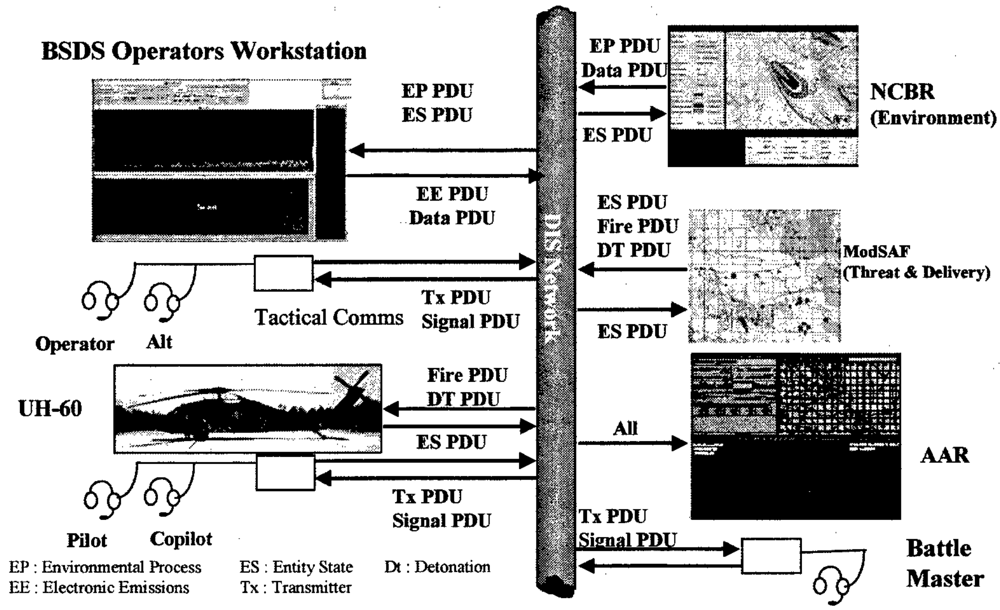

Figure 7. LIDAR Study Architecture.

These simulations were linked into a central viewer and data analyzer (SIMULYZER) via a distributed network domain. This process enabled both an engineering examination of the system and use dynamics in an engagement environment. The structure of the architecture permitted both modifications of the system and the methods in which the system was used.

4.2 BioSIM Results.

The evaluation and enhancement of TTP for the LR-BSDS were successfully achieved. Results of the BioSIM experiments follow.

4.2.1 LR-BSDS Study Results.

- The experiment analysis resulted in modifications in TTP.

- Experimental results also led to LR-BSDS system software modifications giving soldiers the ability to change performance settings originally inaccessible in the field.

4.2.2 Simulation Proof-of-Principal Results.

- Demonstrated viable process to permit parametric modification to handle model inadequacies and scenario adjustments

- Demonstrated ability to engage the system beyond the previous simulation dynamics due to increased modeling capability of the VPS methodology

- Recognition of previously invisible LR-BSDS system limitations due to the linkage of the flight dynamics and man-in-the-loop activities not previously available

- Demonstrated architecture provided 'context' for experimenters enabling reusability

- Demonstrated ability to exploit the architecture for other applications such as training or evaluation of interplay of different existing and candidate systems or warfighting techniques.

5. VPS DEVELOPMENT EFFORTS

This section documents VPS development efforts through FY03. A brief description of work prior to FY03 is presented for history reference.

5.1 Pre-FY03 Efforts.

The Virtual Prototyping concept for evaluation of chemical and biological defense systems was first presented for review by various members of the CB community in a white paper by Michael Kierzewski of the MS&A Team in August of 2001. Commodity and Business Area Managers, material developers, and other subject matter experts in several different CB fields provided commentary on the paper that resulted in a series of refinements to the original concept. Ideas presented as part of the initial reports include:

- Extending the use and improving the fidelity of T&D models used to evaluate detection devices and CB protective clothing to all areas of CB defense equipment

- Taking advantage of a virtual simulation environment to perform testing that would be otherwise illegal, dangerous, or infeasible

- Packaging systems in such a way so as to be useful in constructive and virtual simulations for the purpose of performing operational analysis

- Incorporate principles of distributed interactive simulation (DIS) so that systems under test can be played against human- and hardware-in-the-loop entities as well as for training purposes

The most significant task prior to the FY03 was the development and implementation of Dial-A-Sensor^{TM}. This effort included a "proof-of-concept" demonstration. The demonstration used an interface that enabled the analyst to control various key performance parameters of the Joint Service Lightweight Standoff Chemical Agent Detector (JSLSCAD) and

immerse it into a simulated chemical environment (CB Sim Suite). The results indicated that the modified sensor behaved as expected demonstrating the feasibility of the virtual prototyping concept.

5.2 FY03 Efforts.

Efforts for the past year fall into the following categories:

a. Development of a notional architecture

b. Capabilities Assessment to include Prospective User/SME Interviews

c. Survey of Commercial-off-the-Shelf products that might serve as a starting point for VPS

5.2.1 VPS Architecture Development Studies.

During FY03 a notional architecture was developed as a basis for VPS design. The notional architecture developed during this effort will be refined as details of additional user requirements and needs are assimilated into VPS design. Issues that were the focus of the FY03 efforts include:

- Access to desirable external libraries
- Combining data from simulations/libraries of differing levels of fidelity
- Distributed simulation issues

The results of this effort have been incorporated in Sections 1, 2, and 3 of this document. The notional architecture developed in FY03 is presented in Appendix D.

5.2.2 VPS Capabilities Assessment.

The capabilities assessment for VPS was generated through a series of stages. The initial stage was to internally outline the desired capabilities for VPS. Personnel involved in this stage included material developers/system engineers, combat developers, and experienced warfighters. The initial list was then compared to the requirements listed in the draft VPS Operational Requirements Document (ORD). A matured initial outline was then given to a group of CB defense personnel to evaluate.

To ensure VPS will provide capabilities consistent with community needs and desires, members of the NBC acquisition community were polled. These contacts included development engineers and managers in various PM offices, Commodity Area Managers, and CBRN Subject Matter Experts. Results from the capabilities assessment were consolidated into performance specifications. The list of contributors, desired capabilities and initial performance specifications is included in Appendix B, Section B.3.

Several common themes appear as a result of the polling process. Most importantly, the need for a tool such as VPS was strongly supported. There was also consensus that a VPS tool would be of great benefit to the warfighter. All those interviewed expressed belief that bringing the systems developer closer together with combat developer and warfighter throughout the acquisition process has the potential to shorten the acquisition life cycle, placing new equipment of operational worth and performance use in the hands of the warfighter more quickly.

From a more technical standpoint the survey contributors indicated that integrating models and data of various levels of fidelity and from different commodity areas presents a significant challenge that must be addressed. To maximize its value, VPS should be easily scalable with out a great deal of intervention from the analyst. Also, to accurately model the performance of systems, a great deal of additional data needs to be collected and more and better models need to be generated, particularly in the areas of human respiratory behavior and effects of CB warfare agents, and logistics models should be incorporated to best measure operational impact. Finally, advances in computing power will improve the speed with which analysis can be made and improved real-time interaction will enable the system under test to be implemented in training situations.

5.2.3 COTS Product Survey.

The Clinger-Cohen Act (Information Technology (IT) Management Reform Act of 1996) mandates that Commercial-Off-the-Shelf (COTS) surveys will be performed prior to development of DoD systems. While the desired capabilities for VPS are complex and somewhat unique, there exist several (COTS) products that could potentially serve as a baseline from which to build a robust and flexible system. Testimonial recommendations, Internet research, and a review of currently available tools produced a set of products with capabilities that are similar those desired for a mature Virtual Prototyping System. A more critical review was undertaken which resulted in a refined list of candidate products that are detailed in Appendix C.

COTS Study Methodology. An extensive market survey was conducted to evaluate COTS and Government Non-Developmental Items (NDI) on which VPS could be constructed. The envisioned Virtual Prototyping System requires many different attributes, including component definition and manipulation, data transfer protocols, and access to various external libraries.

In context of VPS desired capabilities and attributes, criteria were developed for evaluation of COTS/NDI software. Because viable candidates come from disparate classes of software, these criteria, listed below, were used to help select and rank candidate software products.

Evaluation criteria of COTS and Government NDI.

- Evaluate the technical ability to meet initial performance specifications as defined during the capabilities assessment

- Evaluate ability of the software to function as documented in this report

- Assess level of effort/ work/integration to make the existing software functional for VPS

- Determine product support infrastructure: existing documentation, configuration management and training

- Determine extent of existing user base for the products.

- Identify any existing libraries that could be leveraged for VPS applications.

- Assess the cost to maintain the core baseline of the COTS/NDI product.

- Evaluate the ability to customize for VPS applications.

- Identify what the product was designed for and how it is being used (robustness, flexibility).

- Assess modularity of the product and ability to support scalability

- Assess ability to support systems views and the systems engineering process

The survey and evaluation process used for this evaluation occurred in three phases. The first phase involved a cursory look across numerous technologies to evaluate the potential for use with VPS. Promising technologies were looked at in more detail for the second phase. Evaluation at this phase took the form of:

- Briefings/demonstrations and developer interviews (LEAPS™)

- Briefings/demonstrations and developer interviews plus additional developer-provided proprietary documentation (SPEED™, MATLAB™/Simulink™, Simprocess™, Epiplex™)

- Experienced prior user interviews (MATLAB™/Simulink™)

- Exploration via sample software and tutorials (Simprocess™, Mathematica™/Optica™)

Several candidate product evaluations were supplemented by additional information obtained via web searches and other public material in addition to user interviews. The third phase of the survey consisted of a culling of candidate technologies to identify a subset for more critical analysis. This culling process was conducted using core MS&A team members, a few knowledgeable researchers, and representatives from the Joint PM for Contamination Avoidance. This final subset of candidates is presented in Appendix C. Final down-select from this list will be made as VPS development continues.

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APPENDIX A

ACQUISITION MANDATES FOR M&S

This appendix is intended only to highlight the salient points of the pertinent acquisition directives, instructions, and policies as they relate to modeling and simulation. The appendix provides the foundation for VPS relevance, fit, and worth to the CBRN acquisition process. It is not intended to be a tutorial on the DoD acquisition process nor is it inclusive of all DoD documents establishing requirements or guidance for M&S in the acquisition process.

A.1 Defense Acquisition System 5000.1, 5000.2 and 5000.2-R Documents

In October 2002, Deputy Secretary of Defense, Dr. Paul Wolfowitz, rescinded Acquisition documents DoD 5000.1, 50001.2, and 5000.2-R, provided interim guidance and directed revision of the cancelled documents 5000.1 and 5000.2. Dr Wolfowitz stated the intent of the DoD 5000 series revisions is to "*...create an acquisition policy environment that fosters efficiency, flexibility, creativity, and innovation.*"

The revised DoD 5000.1 Directive (May 2003) states that Test and Evaluation support be employed throughout the defense acquisition process and include the integration of M&S with T&E processes. The DoDI 5000.2 elaborates on the use of M&S and states that Program Managers shall plan for M&S throughout the acquisition life cycle.

The 5000.2-R is now no longer a regulation but has been retained as a guide. This document provides expectation for best practices and portrays the importance of early system definition in cost and schedule reduction.

A.2 Chairman of the Joint Chiefs of Staff Instruction (CJCSI) 3170.01C

The purpose of CJCSI 3170.01C is "...to establish policies and procedures of the Joint Capabilities Integration and Development System (JCIDS)." These procedures "..support the Chairman of the Joint Chiefs of Staff (CJCS) and the Joint Requirements Oversight Council (JROC) in identifying, assessing and prioritizing joint military capability needs as specified by (the JCIDS process)".

The CJCSI asserts that the identification of capability gaps and potential solutions must be supported by a robust analytical process, a process that, among other processes and tools, includes M&S.

A.3 Simulation Based Acquisition (SBA)

Simulation Based Acquisition (SBA) process is a major initiative within DoD. The goal of SBA is produce quality systems of high military worth, faster, and at lower cost than traditional means. The DoD continues to improve the acquisition process as addressed by the Simulation-Based Acquisition (SBA) process initiative. This initiative, formalized in the revised DoD 5000 series, includes the development of M&S virtual prototyping capabilities in all services.

In the M&S Domains (RDA, ACR, and TEMO) the purpose is to intelligently utilize M&S technologies throughout the acquisition process. Models and simulations are reusable and interoperable across different acquisition phases and activities. The interface and sharing of M&S tools and technologies across the M&S domains is defined by Simulation and Modeling for Acquisition, Requirements, and Training (SMART).

APPENDIX B

CAPABILITIES ASSESSMENT

B.1 Initial Capabilities Assessment. The following people contributed to the initial capabilities assessment.

1. Walton Dickson, MANSCEN
2. Sonia Taylor, MANSCEN
3. Nancy Kammerer, PM NBC Defense
4. MS&A team members, ECBC

B.2 Survey and Interviews: The summaries in this section are identified by the contributors and contain the salient points of their position.

B.2.1 Linwood Halsey, Joint Services Lightweight Standoff Chemical Agent Detector, interview date: 4 Mar 2003

Mr. Halsey provided us with some system schematics of the JSLSCAD. Comments related to VPS requirements include:

- Provide a test chamber environment in the toolset to allow for comparison between the various test methods.
- Ability to specify data output file format (i.e. ASCII, binary)
- Meet JTA requirements
- Allow for Error and Bug Reporting

B.2.2 Kirkman Phelps, Contamination Avoidance Commodity Area Manger, interview date: 9 Apr 2003.

Mr. Phelps' comments include:

- Common tool for Training, Testing and Design
- Link/Interface with other tools
    - Engineering Analysis (FEA)
    - Computer Aided Engineering/Design
    - Electronics Design

- Optics software
- Physics Based Software
- Physics (First Principle)

- Easily Scalable

B.2.3 Mike Abaie, Artemis Program, interview date: 25 Apr 2003

The process to select a software package to model system was initiated. This effort was cut short to use SPEED™.

- Wanted a library of current systems
- Concept of Operations (CONOPS)

B.2.4 Steven Gotoff, Patrick Air Force Base, (Steel Centurion), interview date: 8 May 2003

At the time of selection for SPEED™, there was no comparable software. Sent him requirements document to review.

B.2.5 Ngai Wong, Passive Standoff Detection Technology, 26 August 2002

Ngai's comments include:

- VPS should answer the question of how quickly an agent needs to be identified, as opposed to merely detected
- Begin with user priorities and work down
- Establish a standard database, perhaps one per Enabling Capability under the JFOCs, into which new critical operationally significant details can be stored and accessed by the entire CB community; VPS's role should be to connect these databases in a meaningful manner
- Establish thresholds of useful knowledge; a researcher at the 6.1 level may need to account for atomic interactions whereas a developer at the 6.4 level probably does not
- The target customer is more likely the operation/tactical level users; perhaps a better name for VPS would be the Operational Technology Simulation Assessment Tool

B.2.6 Sandy Quinn, Decontamination Technology, 19 August 2002

Sandy provided assistance in constructing a schematic diagram for the decontamination process. Her comments included:

- Proper simulation of the decontamination process would account for logistics burdens; sustainability an issue at engagement level and above. Decon requires lots of water and systems depend upon significant power supply: generators, batteries, etc.
- Fidelity of simulation might dictate different modeling techniques. For simulation at the:
  - Phenomenological level, use chemistry
  - Engagement level and above, use time blocks
  - Engineering level, some combination of both
- Use field data to generate success rate algorithm to determine if process needs to be repeated

B.2.7 Bill Fritch, Joint Services General Protection Mask (JSGPM), 17 September 2002

Bill took part in test trials for the JSGPM and compared those results with predictions made by the Respiratory Encumbrance Model (REM). His comments include:

- The factors that impact mask performance are complicated and difficult to model because of variations in different users, such as:
  - Respiratory system health and performance
  - Face size and shape
- An important part of VPS should be the inclusion of or connection to an effective Human Behavior Model
  - These models are not very mature and lack fidelity
- Stochastic, as opposed to deterministic processes, are probably better suited to determine outcomes for mask performance at engagement level simulations
- At this time, it is still cheaper and faster to quickly construct physical prototypes to evaluate new concepts

B.2.8 Dave Caretti/Karen Coyne, Respiratory Protection Technology, 25 September 2002

Dave led the effort to create the REM, a GUI driven model designed to aid engineers and physiologists determine the effects of changes to specific mask attributes on mask and user performance. Karen's research focuses on the complex interactions of the factors that influence respiration and basal metabolism. Their comments include:

- REM did not correlate well with results of field tests for JSGPM

- Many variables play a role in respiratory performance, including:
  - Health
  - Weight
  - Core body temperature
  - Humidity inside and outside of system
  - Activity level and duration
  - Environmental factors
- Effective models would require
  - Significant computing resources
  - Improved understanding of human behavior and response to outside stimuli
- Physical prototypes are still easier and cheaper to construct when evaluating effects of attribute changes

B.3 VPS Initial Performance Specification List. Based on interviews and contributions the list below is a compilation of performance requirements for the Virtual Prototyping System toolset.

1. CB Systems to be Modeled
   a. Contamination Avoidance
   b. Collective Protection
   c. Decontamination
   d. Individual Protection
   e. Information Systems Tools
2. Stand-Alone Tool
   a. Evaluate System
   b. Provide Input and Get Output
3. Environments Library
   a. Lower Fidelity, Easily Reproducible Environments
   b. Test Chamber Representation

4. Distributed Simulation

   Immerse System into Synthetic Environment

5. Detailed Evaluation using SAFs

6. Multiple and Disparate System Evaluation

7. Extensive Component Library

8. Output Model of System/Sub-Systems without the overhead of unnecessary code

9. User Defined/ User Modified Components

10. Output to Pertinent Commercial Tools

11. Ability to exchange multiple fidelity models into system representation

12. Components will have definable inter-relations

13. Open Architecture

14. Open Source

15. Interchangeable modules

16. Ability to run different system configurations in a batch process

17. Produce a system representation with major sub-components in a relational structure (with a multi-fidelity representation)

18. System model can be immersed in JEM and JOEF

19. Established systems can have an output model to be distributed in simulations (i.e., JOEF) without the need for VPS code.

20. Ability to specify output format (i.e., ASCII, binary)

21. Produce data for analysis

    a. High/Low fidelity options

    b. Save/ Over-write data options

22. JTA Compliant

23. Built in identifiers that will establish software integrity

24. Error and Bug reporting

25. Configuration Management

    Controlled releases

26. Verification, Validation and Accreditation

APPENDIX C

COMMERCIAL OFF-THE-SHELF (COTS) SURVEY

Those COTS and Government NDI software packages identified in the third phase of the selection process are presented here (Section 5.2.3 for details of the selection process.) They have been ranked based on VPS selection critical and recognized applicability to VPS applications. These packages and the rankings are given in Table C.1. Details concerning each package are in the following sections of this appendix.

Table C.1

Identification and Ranking of Candidate VPS Software

Software Package	Ranking	COTS or G-NDI
Mathematics Laboratory/Simulation Link (MATLAB™/Simulink™)	1	COTS
Simulation for the Performance Evaluation and Exploitation of Designs (SPEED™)	2	COTS
Simprocess™	3	COTS
Epiplex™ Solutions: Process Development Environment	4	COTS
Leading Edge Architecture for Prototyping Systems (LEAPS™)	5	G-NDI
Mathematica™ and Engineering Systems Libraries such as Optica™	6	COTS

The sections below provide comments, descriptions, and brief reviews concerning the products in Table C.1

C.1 Mathematics Laboratory/Simulation Link (MATLAB™/Simulink™)

Major Advantages: **(1) existing user base for CB defense system; (2) extensive documentation and user training available; (3) extensive libraries (signal process, networks);(4) additional libraries can be added; (5) demonstrated HLA/DIS capability and availability; (6) very strong systems engineering processes capability.**

Disadvantages: **requires user expertise / mitigated by available training.**

MATLAB™ is a platform for performing a variety of technical computing tasks including algorithm development, generating tables and graphs, running software simulations, and analysis. The user can implement any calculation by writing routines in several languages, including C, C++, and FORTRAN. MATLAB™ provides many built-in algorithm toolboxes that include formulas from many fields without the need to write code such as:

- Signal and image processing
- Data analysis and statistics
- Mathematical modeling
- Control design

Output can be made available using various included statistics tools, graphically, or in text/table format.

Simulink™

- Works in conjunction with MATLAB™ via its neatly transparent link
- Provides drag-and-drop functionality for joining components and systems
- Additional libraries for commonly used:
    - Components
    - Processes
    - Algorithms
- Allows for introduction of new/novel components

While using the built-in functions and components is easily done, definition for new components specific to CB require that either new objects be created and added to the resident set of libraries or that the systems engineer be very knowledgeable about the working of the component and capable of writing code to make Simulink™ work easily.

C.2 Simulation for the Performance Evaluation and Exploitation of Designs (SPEED™)

Major Advantages: **(1) currently used in a CB acquisition (ARTEMIS) program;(2) ability to customize software (i.e., user can modify core source code).**

Disadvantages: **immature documentation and training.**

SPEED™ was developed to assist in the concept development and pre-design stages of optical sensors. It is an object-oriented program that provides a drag-and-drop, black box approach where an object's properties are user-defined. Right clicking on a component's box opens a GUI that allows the user to define an object's pertinent properties. Adding simple line connectors between the sub-components of a system can link component objects, which can subsequently be recognized as new systems or sub-components of larger systems. Systems can be linked similarly to other objects that include environment objects such as atmospheric properties and terrain features.

SPEED™ Features:

- Uses XML for database definitions
- Links with Open Database Connectivity (ODBC)-compliant databases
- Is HLA-compliant

Core Model:

- Written in C++ (contains some source code in FORTRAN run as an executable)
- Various Output Formats
    - Text
    - Tables
    - Graphs
- Provides the analyst with the ability to define statistically significant values (confidence intervals, performance thresholds, etc.)
- Built in mathematical analysis tools

SPEED™ does require significant computation power and processing speed as a result of this flexibility. While SPEED™ is flexible and powerful, it does require fairly expert input decisions and, at this time, is well developed only for engineering associated with sensors and optical systems. However, the architecture may be appropriate for any set of engineering systems with the inclusion of additional properties/parameters libraries.

C.3 Simprocess™

Major Advantages: **(1) architecture support of systems engineering process; (2) good documentation.**

Disadvantages: **not yet used for CB simulations – primarily used in business applications.**

Simprocess™ is a flexible, easy to use systems modeling tool that was developed primarily to model business practices and methods. Users create a set of "black boxes", each of which represents a particular object or process.

- Easily defined parameters
- Boxes linked by drag-and-drop connectors
- Alerts user to improper connections
- Double-clicking on a process/object allows the user to define and assign properties and/or parameters to sub-components of the system
- Provides a suitable framework for analyzing a system-of-systems.
- SIMPROCESS™ Output:
    - Table, text or graphical
    - Includes flexible statistics package
    - Can be used on intermediate or final results
    - Option to observer output real-time

Simprocess™ is easy to use and understand. However, re-use of components is difficult (no drag-and-drop library for components). Further, significant effort would be required to build complex components (see reference 13)

C.4 Epiplex™ Solutions: Process Development Environment

Major Advantages: **(1) similar capabilities as SIMPROCESS™; (2) plug and play links to other windows applications.**

Disadvantages: **not yet used for CB simulations – primarily used in business applications.**

Epiplex™ is an XML based process analyzer and capture system, which is used for a variety of purposes within the software community. It was initially developed to provide software system process capture for the development of training documentation and intervention (macro) construction. However, the power of the process rapidly grew to include the capability for

cross-application/system capture, documentation, intervention-engineering, and process data capture/analysis. Specific Epiplex Modules include:

Epiplex™ Remote Process (Knowledge) Capture System (ERPCS)

- Spontaneously capture (remotely) processes in use across enterprise
- Store and catalog Process in Enterprise Repository

Epiplex™ Business Process Analyzer (EBPA)

- Analyze, evaluate and identify broken and processes efficiently
- Rapidly develop process models and best practices
- Simplify user feedback and confirmation of process improvements

Epiplex™ Knowledge Provisioning System (EKPS)

- Integrate multiple enterprise applications and workflow products with common user interface
- Embed knowledge into processes and common user interface
- Embed manual processes into common user interface
- Automate user side processes
- Auto-generate business process content such as simulation based training, "How-To" Documentation and "Show Me" Animation
- Provide seamless environment to manage and integrate content from disparate environments and systems

Epiplex™ Process Benchmarking System (EPBS)

- Easily define and set up real time process intelligence for key personnel
- Rapidly set up best practice and process performance benchmark

Epiplex™ Desktop Knowledge Capture (EDKC)

- Capture processes to feed
- Assessment of best practice compliance
- Real time process intelligence and process performance evaluation

Epiplex™ Desktop Knowledge Provisioning (EDKP)

- Track user context to extract from Enterprise Process Repository precisely relevant
  - knowledge, best practices, information and references
  - user process performance support and automation resources
- Obtain business process simulation based training, how-to documentation and "show-me" animation
- Personalized content

Epiplex™ Process Intelligence Dashboard (EPID)

- Obtain real-time intelligence on processes
- Obtain real-time process performance information
- Personalize dashboard

C.5 Leading Edge Architecture for Prototyping Systems (LEAPS™)

Major Advantages: **(1) indirect links to engineering solid model and indirect links to finite element analysis; (2) Object Oriented Programming.**

Disadvantages: **(1) legacy codes in system that must be maintained while developing CB applications – LEAPS is designed for ship and submarine acquisition; (2) very limited documentation; (3) limited use of COTS.**

LEAPS™ was initially designed to improve the Navy's ship and submarine acquisition process. It provides a framework for model interaction and uses an object orient data structure. The primary focus of LEAPS™ is as a transition between engineering design and engineering analysis.

- Design models are converted and stored as tessellated models
- Tessellated models can be viewed through web interface
- Metadata and attributes are associated with the stored models
- Users utilize an API to develop their product meta-models and translators

The LEAPS™ infrastructure resides at the Naval Surface Warfare Center, Carderock Division (NSWCCD) and is run from remote locations via the API. At the user level, all that is required is a desktop computer and a data port. While it is very powerful and flexible, it appears that LEAPS requires that the analyst be very knowledgeable in specific fields of engineering and could entail significant training to maximize its power

C.6 Mathematica™ and Engineering Systems Libraries such as Optica™

Major Advantages: **mathematical processes are very strong.**

Disadvantages: **(1) linking of components to build systems is limited; (2) distributed capability not demonstrated.**

Mathematica™ is a powerful and flexible computation tool providing a platform for performing calculations on data - either present within the application or provided by an external source - and manipulating and combining symbolic expressions, a process Wolfram, Inc. refers to as *symbolic programming*. It comes equipped with tools for:

- Manipulating matrices
- Solving algebraic and differential equations
- Performing statistical analyses

Mathematica™ can be extended to include user-defined processes by means of scripts in Maple or other scripting languages or routines written in C, Java, or other standard languages. However, while Mathematica's power is virtually unlimited at the basic math and computational level, it does not provide the ability to graphically group and manipulate systems as encapsulated objects. Ideally, a systems engineer wants the means to package together and control a set of object attributes and easily connect objects to perform evaluations on both isolated systems and systems-of-systems. While Mathematica™ may have great use as a module for performing specific, clock-time intensive calculations, it would require significant energy and resources to build the graphical user interface or some other relatively easy input method necessary to make it ready to serve as the building block for a systems engineering analysis tool.

Optica™ Optica™, a product by Wolfram, Inc., makers of Mathematica™, is a module designed specifically to extend the functionality of Mathematica™ for the purpose of solving problems in ray optics. Its connection to Mathematica is similar to the relationship between MATLAB™ and Simulink™. Optica™ provides a variety of built-in optical elements such as

- Lenses
- Mirrors
- Gratings, and
- Prisms

Attributes, such as shape and refractive index, can be varied by analyst input. A catalog of common optical media such as glasses, crystals, and fluids, can be used as is or be modified to create new components with unusual shapes and properties. Optica™ has drag and drop palettes that include standard optical elements, as well as electronic and solid state components, all of which allow for some user defined parameters. While Optica™ offers flexibility and can be used

easily, the focus of Optica™ is on investigating basic optical phenomena and may not be suitable for evaluation of complex, engineered systems.

APPENDIX D

VPS NOTIONAL ARCHITECTURE

The VPS Toolset is a modular, data driven simulation tool where the scientist/engineer/analyst controls input parameters and simulation operation through a graphical user interface and have the option of viewing the results in a variety of output formats. Data for the simulation is stored in external, linked libraries. When additional data is or a correction to existing data becomes necessary, changes can be made in the databases. Hard code changes to the core models are not required.

Figure D.1 is a depiction of the 1st Tier Architecture for the VPS Toolset. The COTS baseline will have libraries added which will provide data for the system representation modules. The items in the lower row of the flowchart are the functional components of VPS that the user will control. JEM, JOEF and other models will be used to increase the overall functionality of VPS.

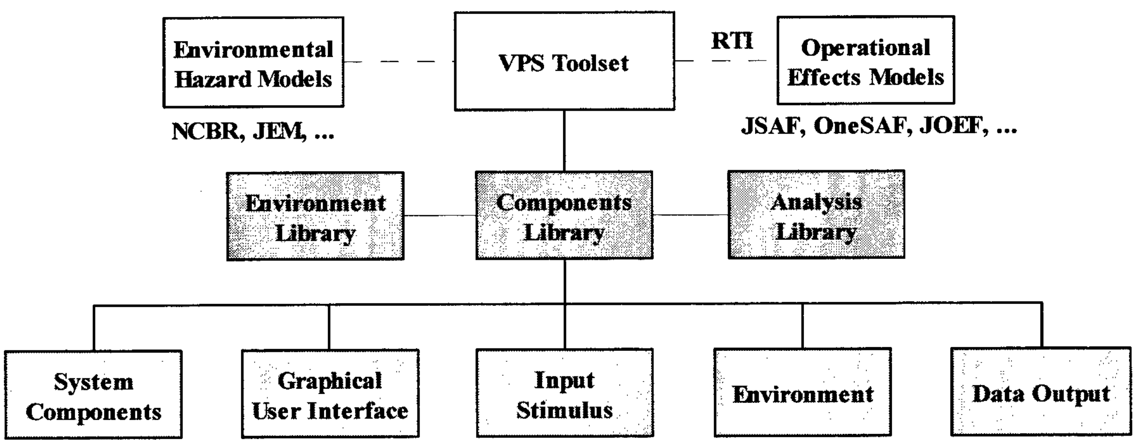

Figure D.1: VPS 1st Tier Architecture

D.1 Commodity Area Functional Flow Diagrams

The following section establishes baseline architecture for the components library of the VPS toolset. The functions of the different commodity areas are broken into tiered structures as defined by the systems engineering process. This outline is chosen as an adaptation of the way that VPS can be used. This organization of the functional requirements can correspond to the modular approach that can be taken using VPS. The upper tier functions could correlate the low fidelity representation of the system. As the system becomes better defined, the functions/components become more developed. The model's fidelity will increase with the maturity of the system development. The diagrams below are intended to be a baseline for

systems in the various commodity areas. Subject Matter Experts (SME) will outline details of the functions related to the systems in their respective fields.

D.1.1 Contamination Avoidance (Sense)

The functional block diagrams below illustrate the components of the CA system. The 1st Tier Functional Diagram (Figure D.2) will contain the information necessary for a low fidelity representation of the system. As the development cycle progresses, the upper tier blocks/modules can be replaced with the lower tier blocks which represent more detailed functional requirements. For sake of expediency, all of the functions will not be expanded in lower tier depictions. This structure lends itself to selecting the fidelity of the model that is appropriate for the system and the task being executed.

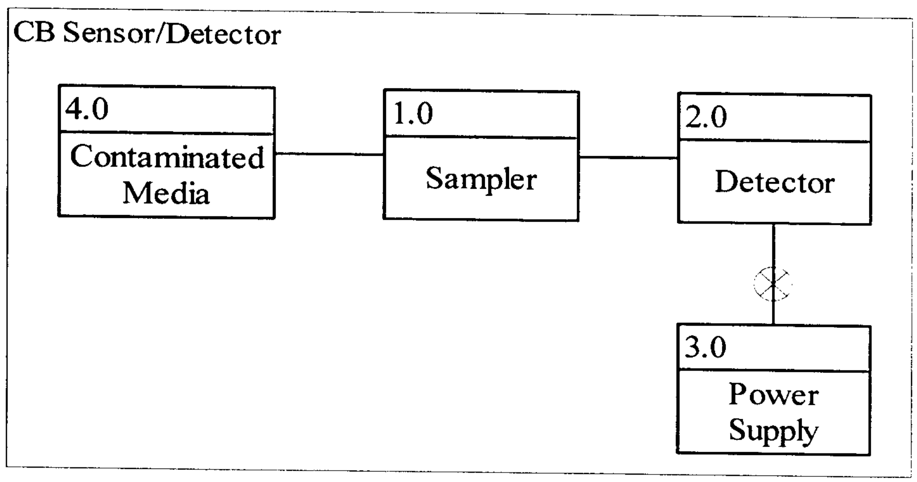

Figure D.2: 1st Tier Functional Diagram for a Contamination Avoidance System

Figure D.3 provides more detail related to the Sampler and Detector functions of a CB Sensor. The 3rd tier, as depicted in Figure D.4, breaks these functions out even further. This process can be continued until the desired fidelity is reached.

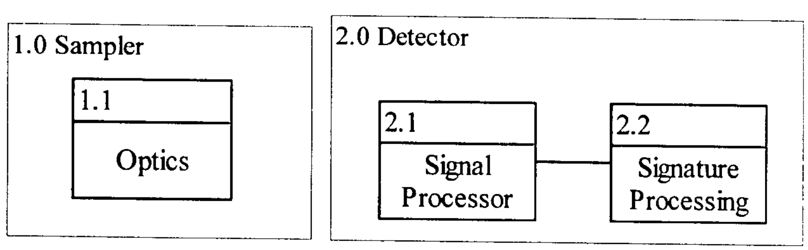

Figure D.3: 2nd Tier Functional Diagram for a Contamination Avoidance System

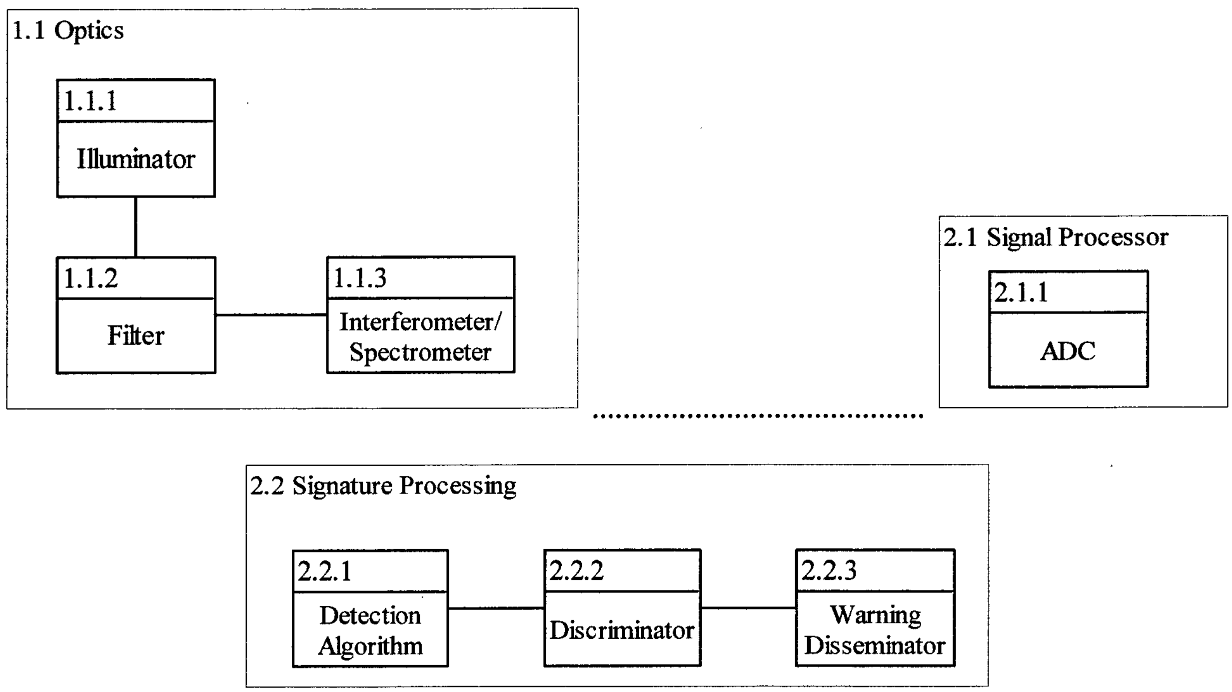

Figure D.4: 3rd Tier Functional Diagram for a Contamination Avoidance System

D.1.2 Protection (Shield)

The figures below represent the functional requirements for a protection system. The basic functions for collective and individual protection are the same. As this is evaluated further, functions related to individual and collective protection will be interchanged such as that of a pump versus human respiration. Figure D.5 is the 1st tier architecture for a protection system.

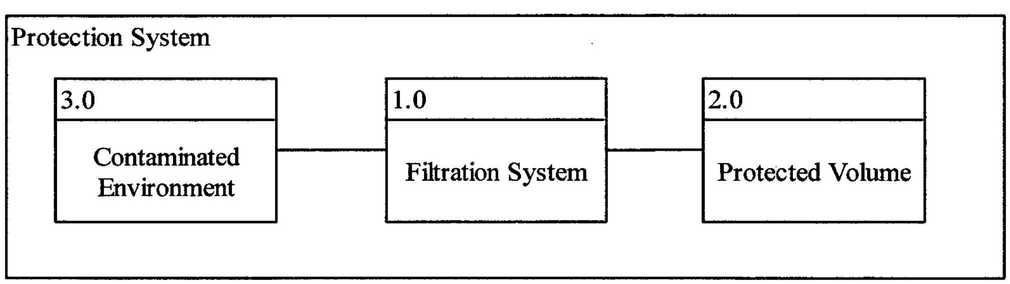

Figure D.5: 1st Tier Functional Diagram for a Protection System

Figure D.6 illustrates the 2nd tier structure of the filtration sub-system of the overall protection system. Figure D.7 expands the functional process of the filtration media into 3 sub-functions.

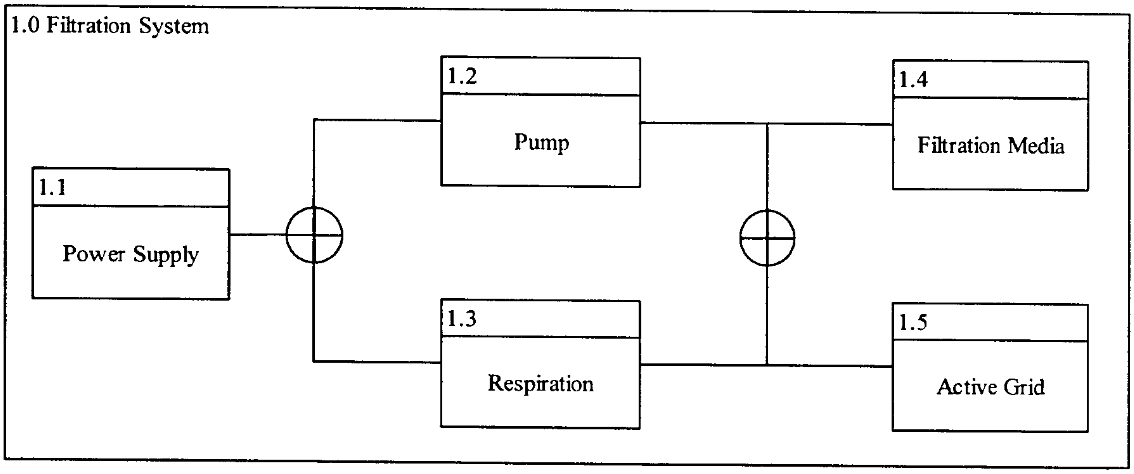

Figure D.6: 2nd Tier Functional Diagram for a Protection System

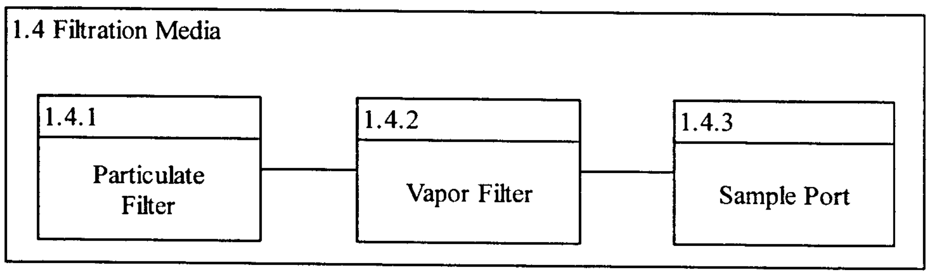

Figure D.7: 3rd Tier Functional Diagram for a Protection System

D.1.3 Decontamination (Sustain)

The functions of a decontamination system are depicted below. The 1st tier of the decontamination system is depicted in Figure D.8. The function chosen to further evaluate is the decontamination system (Figure D.9).

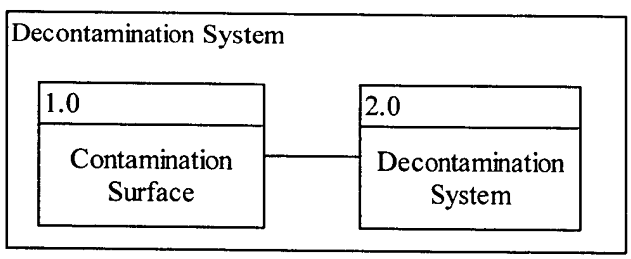

Figure D.8: 1st Tier Functional Diagram for a Decontamination System

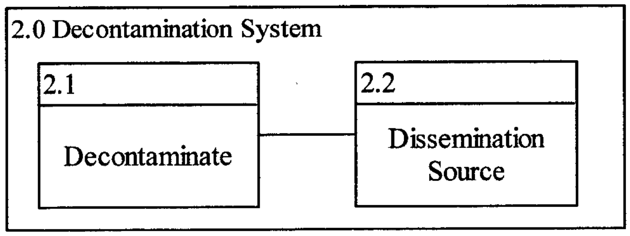

Figure D.9: 2nd Tier Functional Diagram for a Decontamination System

The 3rd tier in Figure D.10 is outlined for a sprayer system. To provide an example of the modularity of VPS, Function 2.1 (Decontaminate) is a point at which a chemistry model can be introduced into the evaluation.

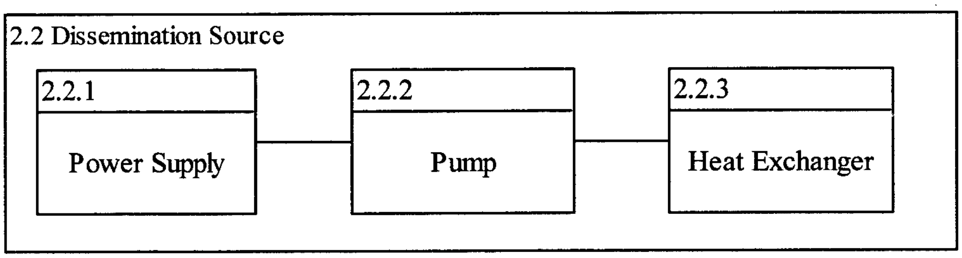

Figure D.10: 3rd Tier Functional Diagram for a Decontamination System

D.2 Investigation/Leverage Areas of Interest

The VPS model has the capability of joining with other, external elements as described in the sections above. The following three areas are of particular interest:

- Common Simulation Framework
- Leverage Model Architecture for Technology, Research and Experimentation (MATREX) Science and Technology Objective (STO) Architecture Layout (Joint approach, Joint Virtual Battlespace (JVB))
- Computer Aided Software Engineering Tools

D.2.1 Common Simulation Framework

The Common Simulation Framework (CSF) is an open-source, government owned system for making simulation systems modular and easily reusable. The configuration management for CSF resides at Redstone Arsenal. The following overview is excerpted from the *Common Simulation Framework (CSF) Programmer's Guide*:

Over the last several years, the simulation community has recognized the need for an object-oriented simulation framework that allows users to assemble component models into simulations in a user-friendly environment. The Common Simulation Framework (CSF) has been developed to address this need. The CSF is implemented entirely in C++. The structure of the CSF is based on a "client/server" model that separates server (model) code from client (GUI) code. When applied to simulation modeling, this structure insulates the models from changes in the GUI code that is often highly platform dependent. To ensure that models developed within the CSF are portable, all models are implemented using server-side frameworks based on the Standard C++ library.[1]

D.2.2 Leverage MATREX STO Architecture

The purpose of the MATREX STO is to develop a persistent, secure, distributed and reusable environment where simulation models and system components can be "plugged" into an established architecture as needed and then "played" for analysis, evaluations and technology trade-offs in support of the Objective Force, Army transformation, other Services, and joint acquisition programs. The architectural development will be leveraged to mitigate development costs for VPS. In addition, the models and tools represented in MATREX will greatly increase the potential functionality of VPS.

The following is a generic description of the MATREX architecture. A detailed explanation of the architecture is provided in the MATREX System Architecture Description, March 03 (Research, Development and Engineering Command). VPS architecture will be governed via the position of common building blocks (standards and interfaces). Figure D.11 (source: Tank-Automotive and Armaments Command (TACOM) Defense Standardization Symposium; DCS Corporation; March 03) depicts this concept graphically.

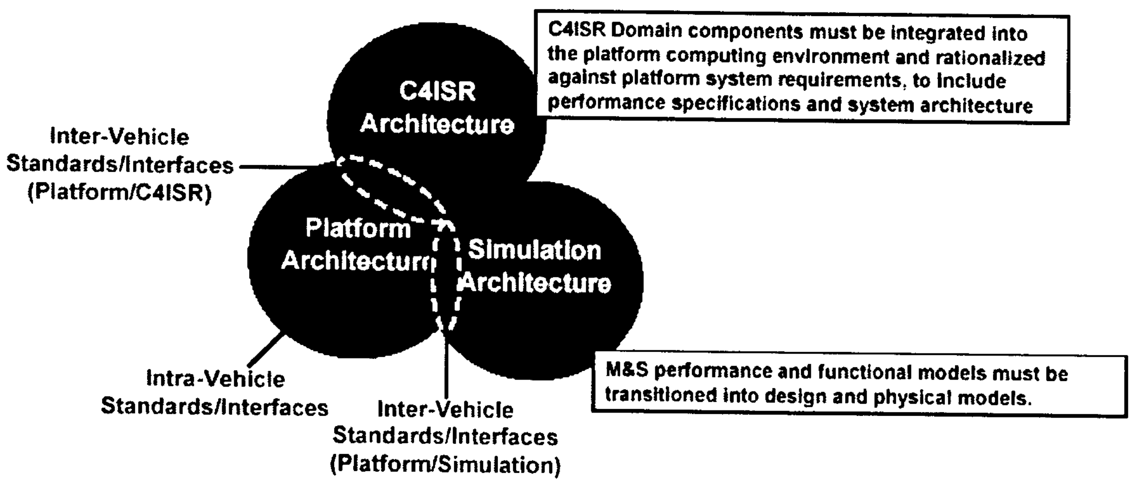

Figure D.11: Architecture Structure for Commonality

The VPS system incorporates existing commonalities to establish linkage via similar structure and interfacing as shown by Figure D.12.

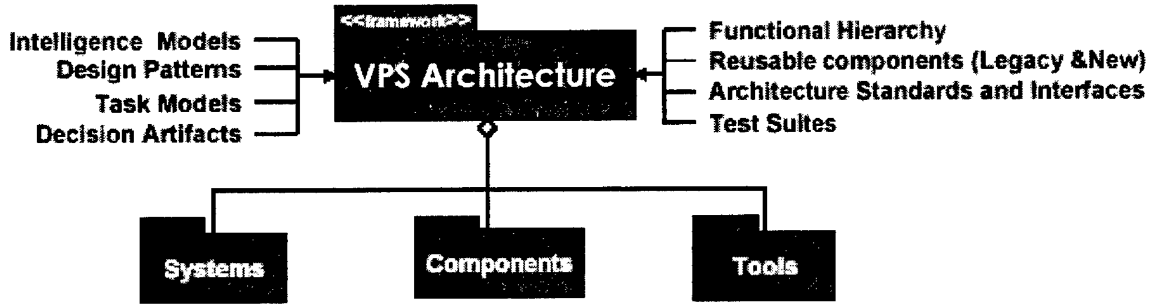

Figure D.12: Commonality Structure

D.3 Data Handling

Data handling will depend nearly exclusively on the model/structure/software selected. It must interface with all external simulations being associated with the VPS processes (i.e., the higher fidelity models). Thus, the structure will need to be associative and visible to each of these architectures.

D.4 Environment Modeling

Environment modeling will be based upon currently accepted simulations. VPS will be open for library interface with these models as required. A basic, 'standard' library will be included in the baseline VPS model for use in a non-distributed structure for initial analysis and modeling. Higher-level fidelity will be achieved via the distributed processing mode.

D.5 Component Modeling

Component modeling is the heart of the VPS simulation. VPS will contain the ability to structure simulation aspects per the requirements of the scientist/engineer/analyst from a list of common algorithms and/or independently constructed models. Additional attributes have been discussed in the information within this report.

Because of the distributed processing capability of the VPS architecture, multiple components may be modeled independently and combined into a structured system for operational analysis. The independent modeling mode also permits independent and sub-component analysis as required by the user.